# A Performance Approach to Training Research

**Charles Vaught, William J. Wiehagen, Edward A. Barrett, Michael J. Brnich, Jr.
Kathleen M. Kowalski, Launa Mallett, Lynn L. Rethi and Robert Randolph**

The goal of the Pittsburgh Research Laboratory's training research is to explore the relationship between valid instruction and improved worker performance. Studies summarized in this paper include: (a) the development and assessment of training techniques that strengthen miners' ability to act competently in emergencies; (b) investigations of classroom simulations that enhance the perceptual, judgment and decision making skills of workers confronted with mine hazards; and (c) field studies of the linkages between financial investments in occupational skills training and measurable outcomes.* The authors maintain that better ties between training and performance will aid long-term human resource development. The best way to establish this connection is through the use of objective and reliable data.

## Introduction

Training for miners in the U.S. is mandated in a series of regulations[1]. These were promulgated under the Federal Mine Safety and Health Amendments Act of 1977[2]. This legislation required mining firms to provide health and safety instruction to new entrants (new miner training), experienced miners (annual refresher training), and workers that are assigned a different job ("new task" training). Regulatory requirements for new miner training and annual refresher training are both *time* and *content* based. New task training requires job specific instruction about the types of hazards usually associated with assigned duties. U.S. industry has been willing to take the outcomes of this training on faith. In other words, very little has been done to establish empirical links between training and profit or between training and safety.[3]

A study[4] concluded the following about annual refresher classes held in 1985: (a) rote instruction was the most common method used by trainers; (b) mine trainers tended to rely heavily on the same sets of audiovisuals and instructional materials year after year; (c) classroom management allowed distractions, complaints, or other activities that were not goal oriented; and (d) the use of innovative teaching techniques (games or simulations) were fairly common but usually limited to the factual recall of safety information. These insights, coupled with what is found generally in safety training literature, underscores certain limitations of the prevailing approach, a course of action that is slowly being changed.

Recent work by NIOSH investigators[5, 6] signals a transformation in the procedures used to teach mine health and safety. This progression includes: (a) instructional technologies that incorporate embedded measurement; (b) materials that are based on extensive field testing and validation; (c) training strategies to locate safety concepts and factual data within the workplace context; (d) a focus on problem solving skills that make active use of factual safety information; and (e) a reliance on small group instructional methods. These studies have stressed the need for an evaluation component that is grounded in educational research. They have produced materials that are practical in their implementation and that appear logical to workers, mine managers, and safety practitioners alike. This paper provides an overview of some of this work.

---

*The authors are indebted to professors Henry P. Cole and G.T. Lineberry of the University of Kentucky. Both individuals were instrumental in the work summarized here.

## Mine Emergency Skills

In 1984 a broad program of research was initiated to develop performance based teaching and evaluation methods for mine emergency skills. Highlighted here are a few of the notable findings from this collaborative effort with University of Kentucky researchers. These relate to: (a) the construction of classroom based problem solving simulations, and (b) training in Self-Contained Self-Rescuer donning procedures. Common to those efforts has been an on-going study of workers' behavior in underground mine fires. This investigation offers rich insight into methods that will help prepare miners for emergency response activities.

People often get into difficulty as emergencies develop because they fail to recognize impending problem situations and therefore delay taking action. They also have difficulty with the information gathering, decision making, and judgment tasks required for effective response to emerging events. Both these areas of deficiency may go unaddressed in mining, because problem solving skills are not usually a part of the instruction workers receive in annual refresher classes. Another way people can get into trouble is by not being able to perform critical physical tasks. This area of deficiency may also go unaddressed in mining, because the skill is taken for granted and never tested. Consequently, a series of performance based instructional materials were developed for the purpose of enhancing workers' proficiency in mine emergency situations. The structure of these materials was influenced by a substantial amount of research concerning how to teach and assess nonroutine skills.

## Paper and Pencil Simulations

Traditional instruction produces learning that is largely "inert".[7, 8, 9] Students tend to remember factual details of the material for only a relatively short time. They also have difficulty using this information to solve problems in the real world. However, instruction can often be arranged to present paper simulations. These problems require individuals to gather and organize information, to recall and apply relevant facts, and to use skills necessary for coping with actual predicaments. During this process "active" knowledge is produced. That is, students are able to apply what they have learned in the classroom to the reality of their lives and work. Under such learning conditions, they are also likely to be highly motivated.[10, 11, 12, 13]

Using accident reports and the help of experienced mine safety personnel, researchers have developed and validated more than 60 simulated predicaments. These require problem solving in two large skill domains: first aid, and self-rescue and escape. Each simulation is contained in a problem booklet that begins with a scenario presented in simple language. Sketches of such things as a mine map and an illustration of the accident scene are included to help further define the predicament. After studying the situation a miner works the problem by responding to a series of choice points. These are offered one to a page. At each of the steps in an exercise a person is required to gather information, make decisions and indicate what action he or she would take. The miner initiates this action by choosing among possible responses contained on a separate answer sheet. Brackets on the answer sheet enclose a message written in invisible ink. There is a message for each course of action listed. When the worker makes a decision and selects an alternative, he or she marks between the brackets with a special pen. The message immediately becomes visible, evaluating the "correctness" of such a response and giving additional information. This information deals with what would likely result from taking such an action in the real world.

An example of such an exercise is one entitled "Escape From a Mine Fire" (EMF). In 1988, a fire forced the evacuation, through smoke, of three section crews from a large underground coal mine in the eastern United States[14]. Numerous errors were committed as miners attempted to evacuate their working sections and find their way to safety. Sixteen workers who escaped this fire were interviewed. Transcripts of these interviews were used as a basis for the development of a paper-and-pencil simulation. This exercise was intended to teach and assess miners' ability to cope with a variety of mine fire contingencies. The problem was designed in such a way that working it would reinforce appropriate choices while correcting errors in miners' reasoning and decision-making.

The EMF exercise content was examined by a group of nationally recognized mine fire and mine rescue experts. Suggested revisions were made and the simulation was field tested. The field test involved carefully controlled administration of the revised exercise to one hundred and thirty-four underground coal miners. Individuals in this sample represented three major job categories found in the underground mining industry: (1) miner-laborers (24.5%) who were hourly employees engaged in various jobs related to the extraction and transportation of coal; (2) maintenance-technical staff (45.3%) consisting of electricians, mechanics, surveyors, and other personnel who work underground in and around the sections; and (3) supervisors-managers (30.2%) who were salaried employees (section foremen up to mine superintendents). On another dimension, 54.5% reported either training, special certification, and/or routine performance in at least one of the following areas of expertise: (1) foreman; (2) mine safety committee; (3) mine rescue team; (4) cardio-pulmonary resuscitation (CPR); (5) advanced first aid; (6) emergency medical technician (EMT); and (7) advanced life support. In other words, most of these workers were highly experienced.

For critical skills like those involved in this simulation, a mastery of at least 90% of the exercise content is a reasonable standard. A lower performance is seen as undesirable because the real-world consequences can be severe. The measure used in this analysis is the exercise's total score expressed in percent correct performance. For this sample, only 16.3% of the individuals attained performance scores at or above 90% mastery.. Although the exercise is designed for those at a basic skill level, a number of persons made errors in critical skills that should be learned to perfection. In addition, nearly 94% reported that they learned something new. This is not particularly encouraging for a group that contained a large proportion of supervisory and technical personnel.

### Computer Simulations

Skills at identifying and correcting or avoiding hazards are a critical supplement to engineering control approaches. Because these skills are unlikely to arise spontaneously, they must be imparted through effective training. Unfortunately, as mentioned above, the effectiveness of the training delivered to the mining community is rarely measured. Interactive instructional technologies such as latent image simulations provide an opportunity to offer training content in a form that can be more readily measured. Prototype interactive training that is based on computerized authoring systems, and that builds upon the latent-image content, has now been developed and is being evaluated through field testing with miners, trainers, and safety personnel. One computerized training tool now completing development is intended for officials who must manage a mine's command center during an emergency. As mines become safer and disasters fewer, the number of individuals who have hands-on experience with mine emergencies is decreasing. A gap in expertise is being created that could have serious consequences at future major emergency events. Because potentially catastrophic hazards are not faced routinely, emergency prevention and response is sometimes given a low priority in training plans. Training for command center leaders is not mandated, and most managers have little or no experience with mine emergencies. Although some emergency response training is available to the mining industry, it can be expensive to conduct and/or not easily accessible to all mining operations.

The goal of the project to produce an emergency response training tool is to reduce the risks associated with infrequent but potentially catastrophic incidents. It will improve prevention and emergency response training (and access to that training) for miners, incident responders, and command center personnel. Methodologies and materials will meet the need for training in limited time frames. Software will help teach command center leaders to coordinate and manage response efforts via computer simulation. This customizable software will allow emergency response experts (including State and Federal agencies) to develop new and varied training scenarios. Delivered via the Internet, this training will be accessible to all U.S. mining operations. The products of this project will be applicable, with some modification, to all mining work sites. Some of the results will also be useful for emergency training in other types of work settings.

### Motor Task Training For Self-Contained Self-Rescuers

Initial studies by the University of Kentucky under a Bureau of Mines/NIOSH contract cast doubt on whether workers would be able to don their oxygen breathing apparatus in an emergency. The researchers found that recommended donning procedures for these "self-contained self-rescuers" (SCSRs) were difficult, inefficient and hard to remember[15]. It was also determined that a majority of underground miners never have hands-on experience with the apparatus[16]. Based on these findings, a new donning procedure known as the "3+3" method was developed. The "3+3" designation came from the three critical steps necessary to isolate one's lungs (activate oxygen; insert mouthpiece; put on nose clamps) and the three secondary steps necessary for effective travel (don goggles; secure straps; replace miner's cap). A training package containing an instructor's manual and short videotaped demonstration were prepared for field testing. The 3+3 training method presents a generic procedure for all SCSRs currently used in the United States (CSE, Draeger, MSA and Ocenco). It offers the following: a set of consolidated procedural rules that facilitate retention; and hands-on practice with evaluation and feedback.

Researchers conducted a year-long experiment with two groups of mining personnel in order to assess the effectiveness of periodic hands-on practice. Both groups were trained on the Draeger OXY-SR 60B SCSR using the 3+3 method[17]. Following initial training, individuals in the experimental group were given a chance to practice donning an SCSR during the course of fire drills or when walking their escapeways. Individuals in the control group were not given the opportunity to receive periodic practice. Members of both groups were then sampled at various time intervals and their donning proficiency assessed.

Approximately 80% of the samples from both groups were proficient in donning their SCSR one week after training. Three months after training, however, only about 33% of the people sampled from both groups performed proficiently. At about ninety days after training, members of the experimental group began receiving periodic donning practice. Additional follow up evaluations of both groups were conducted at six, nine, and twelve months after training. The experimental group consistently had a higher percentage of miners who were proficient in donning their SCSR than did the group that did not receive practice. Clearly, these evaluations show that periodic hands-on practice is necessary for maintaining SCSR donning proficiency.

### *Impact On Miner Training*

The products of this emergency skills research were designed to work well across a variety of settings. This fact is shown by the distribution of almost a half million simulation answer sheets and general adoption by the coal industry of the 3+3 SCSR donning method. The impact of widespread use does not stop with specific exercise content, however. Many instructors use their experience with the materials to develop ideas and insights for other classroom activities. The paper and pencil simulations demonstrate new ways to approach discussions of hazard recognition and correction, accident prevention, and emergency response procedures. The SCSR exercise demonstrates simple means by which to conduct performance oriented task training, because its methods can be generalized to other tasks that require manipulation of equipment and knowledge of procedure. And, the increased efficiencies available through computer technologies offer better results from the scarce resources available. In sum, the results of all field tests suggest these approaches have tremendous potential to improve mine safety training.

## Mine Occupational Skills

The second theme of the Pittsburgh Research Laboratory's training research addresses methods for teaching and measuring task proficiency within a routine context. Current work is focused on two key aspects of this investigation. The first involves teaching hazard recognition skills. In mining, as in most other production-related industries, a worker's safety is dependent upon his or her ability to recognize hazards in the workplace. Information needed to recognize these hazards is often available in the form of visual cues found throughout a mine. Researchers are exploring ways to make miners more aware of these cues. The second effort entails development and field testing of a cost/benefit model that can be used to structure training for underground work crews. This Work Crew Performance Model attempts to define variability within workers' performance of similar tasks and relate observed variability to a cost consequence.

## Simulations Using Three-dimensional Slides

In the United States, methods for teaching mine hazard recognition in the classroom have not changed much over the years. The format for such training usually consists of having workers view slides of hazards or participate in discussions of conditions in their workplace. These training approaches assume that informing workers of "problems" will have some impact at a later time when a miner happens to encounter similar hazards on the job. Any concerns about whether learning will be transferred from a classroom to the workplace are rarely addressed.

The need for improved methods of teaching miners to recognize hazards was addressed by using an innovative form of instruction. This instruction combines the known advantages of latent image exercises, discussed earlier in this paper, with Three-dimensional (3-D) slides. Adding 3-D slides to a paper-and-pencil simulation forms a truly unique training instrument. It figuratively "places" miners in a problem-solving situation that they can visualize realistically using high fidelity three-dimensional pictures. Although these training materials are appealing, little was known about whether they lead to any improvement in hazard recognition skills. Nor was it known how this learning might transfer to the workplace. Researchers posed the following question: Can training which uses a latent image/3-D slide exercise improve a miner's ability to recognize roof and rib hazards? To answer this question, they conducted two hazard recognition experiments with small samples.

Six coal miners with similar job classifications and mining experience participated in the first experiment. The miners were assigned randomly to either an experimental group or a control group. The experimental group was trained with a latent image/3-D slide simulation. This was done in a classroom at their mine's training center and took approximately thirty minutes to complete. Each miner worked individually through his problem booklet and responded to the questions. At certain points, exercise directions had the worker view a designated 3-D slide that accompanied a particular question. There were no discussions during the training session and each miner worked at his own pace.

To investigate the effectiveness of this training, a hazard recognition task was set up in the mine. Twelve areas that contained roof and rib hazards similar to those found in the exercise were identified. These areas were part of a mile-long route traversing two of the mine's major entries. Each area was marked by spray painting a letter, A through L, on the ribs of the entry. No artificial hazards were prepared at any area; only ones that existed naturally were recorded. These then became keys for the recognition task.

Hazard recognition performance was assessed as subjects from both groups walked through the mine and attempted to identify hazards in each marked area. For the underground walk-through, each miner was given a pencil and clip-board with twelve sheets of paper labeled A through L. The workers were instructed to walk as a group along the designated route and stop at each labeled station. They were given one minute at each stop to identify any roof or rib hazards they recognized. Subjects wrote their observations on the sheets provided. These written responses were done individually. At no time were group members permitted to talk to each other or discuss the task. Researchers provided no feedback at any time during the entire experiment.

**Table 1. Performance scores on underground hazard recognition task.**

| | individual scores | | group scores | | | |
|---|---|---|---|---|---|---|
| Group and subject | number | percent | mean number | std. dev. | mean percent | std. dev. |
| Control | | | 10.7 | 2.5 | 53.3 | 12.6 |
| 1 | 11 | 55 | | | | |
| 2 | 13 | 65 | | | | |
| 3 | 8 | 40 | | | | |
| Experimental | | | 16.3 | 1.5 | 81.7 | 7.6 |
| 1 | 18 | 90 | | | | |
| 2 | 16 | 80 | | | | |
| 3 | 15 | 75 | | | | |

There were twenty possible points for the underground hazard recognition task. Table I shows the individual subject scores. These are given as both the number correct and a corresponding percent correct. The table also provides means and standard deviations for both the control and experimental groups. Note that all subjects in the experimental group, who had training prior to the walk-through, scored higher than the control group. The control group, of course, did not receive training prior to the walk-through. Given the small sample size, a Fisher Randomization $t$ Test was applied to the data. This test confirmed with 95% confidence the hypothesis that the mean experimental group score was significantly greater than the mean control group score.

The subjects in the second experiment consisted of five veteran coal miners with similar underground experience. They were all members of one production crew. Their section foreman selected these workers to participate in the study. Each individual was trained at a time when it was convenient to break away from his regular job responsibilities on the shift. A repeated measures design was used in this experiment. First, ten areas were identified along a one-mile route in a main intake air course. This route contained hazards similar to those that were to be presented in the exercise. All miners were pretested on the hazard recognition task during a walk-through of the areas. Next, training was conducted using the same latent image/3-D slides simulation as in the first experiment. Then a post test on the hazard recognition task was administered during a second, identical walk-through. As in the first experiment, there were no discussions during the entire session.

Table 2 shows the number and percent of correct responses for each subject on both the pretraining and post training walk-throughs. The means and standard deviations for each of these scores are also provided. A Fisher's Exact Matched-Pairs Test was conducted. It indicated, with 95% confidence, that the post training scores were significantly higher than the pretraining scores. As in the first experiment, a greater number of hazards were recognized by miners after training. Further, because these hazards were recognized underground following classroom training, this innovative instructional approach appears to have a certain transfer utility.

**Table 2: Pretraining and posttraining performance scores on underground hazard recognition task**

| | *Pretraining* | | *Posttraining* | |
|---|---|---|---|---|
| Subject | Number correct | Percent correct | Number Correct | Percent correct |
| 1 | 7 | 41 | 10 | 59 |
| 2 | 3 | 18 | 7 | 41 |
| 3 | 9 | 53 | 12 | 71 |
| 4 | 4 | 24 | 6 | 35 |
| 5 | 7 | 41 | 8 | 47 |
| Mean: | 6.0 | 35.3 | 8.6 | 50.6 |
| Std. dev. | 2.4 | 14.4 | 2.4 | 14.2 |

In addition to the above study, experiments have been designed to determine if "degraded" training materials have application for hazard recognition instruction in the mining industry. Degraded pictures, sometimes used by the military to train pilots, are ones in which the target is partly hidden naturally rather than highlighted[18]. Experimental and control training materials were developed and tested with eighty-two miners in the eastern United States. Subjects in the control group were shown highlighted hazardous ground conditions such as a joined roof. Subjects in the experimental group were shown the same joined roof but within its environmental context. This included other roof faults, a water hazard and treacherous walking conditions. The experimental group was forced to discern among these hazards. Experimental group subjects performed better on a hazard recognition measure than did miners in the control group. Results of this analysis are presented in Table 3.

**Table 3: Comparison of Experimental and Control groups on a hazard recognition performance test using Student's *t*-test.**

| Group | N | Mean | Std. dev. | $t$ |
|---|---|---|---|---|
| Experimental | 40 | 14.85 | 4.12 | 3.12* |
| Control | 42 | 12.00 | 4.15 | |

*$p$ <.01

It was concluded that the degraded method of training provided workers with an increased ability to recognize hazards in the mining environment. This type of instruction, as well as the latent image/3-D exercises, has a potential to improve the hazard recognition skills of miners. In the future, it could impact their workplace safety.

## A Cost/Benefit Model For Training

This section will discuss the development of a model that can be used to identify and structure training investments for underground work crews[19]. The Work Crew Performance Model (WCPM) helps to define performance variability within similar tasks. This is done by using work site observations that determine adherence to job elements contained in a standard operating procedure (SOP). Observed variability may then be related to a cost consequence. Key components of the WCPM include: (1) job definition through task analyses; (2) the ranking of job elements by perceived cost consequence; (3) observational techniques that establish performance baselines; and (4) cost linkages between adherence to procedures and the consequences for noncompliance.

An important principle of the WCPM is its reliance on *learning* from a veteran workforce and using that information to *reinvest* in strategies that enhance quality output. Quality can be measured along two dimensions: *how much* is produced, and *how safely* the product is mined. The WCPM measures behavior relevant to an operator's task by assessing the relationship of errors to the primary accomplishment of his or her job. In the case of a shuttle car operator, that accomplishment might be to minimize the amount of time a continuous miner has to wait for an empty shuttle car. In the case of a continuous miner operator, the accomplishment might be to maximize load time as a percentage of shift time.

To illustrate: For shuttle car operation, SOPs typically recognize fifty to one hundred specific items. Only a portion of these, however, defines performance errors that *significantly* impact the operator's job accomplishment. Any practical utility of these lists is limited without associated information. The relative frequencies of tasks or sub-tasks must be known. There must be an estimate of the probabilities that error occurrence will have a direct and important impact on work crew safety and productivity. Without such information (i.e., a norm), one could expect significant variability within the job task. This variability might be dependent upon individual perceptions of accomplishment, task experience, risk taking, equipment design, work procedures, or the management system. The research objective is to show how job accomplishment can be attained with a minimum negative impact on safety and productivity.

The WCPM was tested through a study of shuttle car operation at an underground mine in the eastern United States. The research team began with a thorough job analysis. Six major task areas were identified: (1) preshift inspection; (2) tramming; (3) loading; (4) dumping; (5) end-of shift activities; and (6) idle time activities. A subset of 48 sub-tasks were recognized, validated and ranked by use of a nominal group technique (Q-sort). The mechanics of Q-sort rely upon individual evaluation and group consensus. The two-stage Q-sort procedure placed each activity (job element) into one of five priority categories based upon perceived cost consequence: (1) Very Low; (2) Low; (3) Medium; (4) High; and (5) Very High.

Using a newly devised behavioral observation checklist for shuttle car operation, researchers observed the performance of three regular and three incidental shuttle car operators over a three week period. The visual observations yielded proficiency estimates. Operator proficiency was calculated by the following algorithm:

$$Proficiency = \frac{no.\ of\ correct\ behaviors\ observed}{total\ no.\ of\ behaviors\ observed}$$

Proficiency profiles were the highest for all operators among those tasks often associated with traditional measures of crew output. It was also found that experienced operators consistently outperformed the less experienced incidental operators in each of the six major task groups. Interestingly, performance profiles for all operators paralleled the Q-Sort sub-task ranking. However, incidental operators' adherence to procedures was substantively below that of the regular operators when analyzed by task or consequence. A linkage between performance errors and production downtime was indicated, but not proven. Replication of the study would need to include larger sample sizes for statistical treatment.

These findings suggest the WCPM could be used as a practical guide for thinking about available choices to reduce performance variability. The model might be used as an evaluation and problem solving tool with veteran as well as novice equipment operators. Field application of the WCPM can offer useful data to support performance improvement strategies (e.g,. training, job design, administrative procedures). These can then be tested for their ability to reduce human error, thereby encouraging greater adherence to critical job procedures.

## Conclusion

A grasp of the relationship between new technology and how workers use it is fundamental to the long-term vitality of mining. A better understanding of variability within the two broad performance domains discussed in this paper can reveal such a link. NIOSH studies in human resources at the Pittsburgh Research Laboratory seek to offer a continuous array of data leading to economically justified training interventions. These data may be used to define realistic goals, methods and procedures for successive improvements in mining systems and work crew proficiency. Such justification will serve to institutionalize increased investments in the workforce.

## Endnotes


1. U. S. Code of Federal Regulations (1993). Title 30 -- Mineral Resources. Washington, D.C.:Office of the Federal Register, National Archives and records Service.

2. Federal Mine safety and Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164.

3. Mangum, S., G. Mangum, and G. Hansen. Assessing the Returns to Training. In A.P. Carnevale, et al. In New Developments in Worker Training: A Legacy for the 1990s. Madison, WI: Industrial Relations Research Association, c. 1990, pp. 55-89.

4. Cole, H.P., Mallett, L. G., Haley, J.V., Berger, P.K., Lacefield, W.E., Wasielewski, R.D., Lineberry, G.T., and Wala, A.M. Research and Evaluation Methods for Measuring Nonroutine Mine Health and Safety Skills, Vols 1& 2. (Contract No. H0348040, University of Kentucky) Bureau of Mines OFR Vol. 1 -18(1)-89, PB 89-196646; Vol. 2 OFR 18(2)-89, PB 89-196653, 1988.

5. Digman, R.M. and Grasso, J.T. An Observational Study of Classroom Health and Safety Training in Coal Mining. (Contract No. J0188069, West Virginia University) Bureau of Mines OFR 99-83, NTIS PB 83-210518, 1981.

6. Cole, H., et al. (1988). op. cit.

7. Bransford, J., Sherwood, R. Vye, N., & Rieser, J. (1986). Teaching thinking and problem solving: Research foundations. American Psychologist, 41 (10), 1078-1089.

8. Halpern, D. (1984). Thought and Knowledge: An Introduction to Critical Thinking. Hillsdale: Erlbaum.

9. Cole, H. (1971). Process Education Englewood Cliffs: Educational Technology Publications.

10. Resnick, L. (1987). Learning in school and out. Educational Researcher, 16 (9), 13-20.

11. Chipman, S., Segal, J. & Glaser, R. (1985). Thinking and Learning Skills. Volume 2: Research and Open Questions. Hillsdale: Erlbaum.

12. Segal, J., Chipman, F., & Glaser, R. (1985). Thinking and Learning Skills. Volume 1: Relating Instruction to Research. Hillsdale: Erlbaum.

13. Mayer, R. (1983). Thinking, Problem Solving, Cognition. New York: Freeman.

14. Miller, R., & Borda, M. (1988). Report of Investigation (Underground coal mine): Non-injury Machinery Fire Cambria Slope Mine No. 33, ID No. 36 00840. Arlington, VA: Mine Safety and Health Administration.

15. Vaught, C., & Cole, H. (1987). Problems in Donning the Self-contained Self-rescuer. In Mining Applications of Life Support Technology (Bureau of Mines Information Circular 9134) (pp. 26-34). Washington, D.C.: Government Printing Office.

16. Cole, H., & Vaught, C. (1987). Training in the use of the self-contained self-rescuer. In Mining Applications of Life Support Technology (Bureau of Mines Information Circular 9134) (pp. 51-56). Washington, D.C.: Government Printing Office.

17. Vaught, C., Wiehagen, W., & Derick, L. (1988). Achieving and Maintaining Competence in Donning the Self-Contained Self-Rescuer. Pres. at TRAM 15 Conference, August 1988.

18. Perdue, C.W., Kowalski, K.M. and E.A. Barrett (1994). Hazard Recognition in Mining: A Psychological Perspective, U.S. Bureau of Mines Information Circular 9422.

19. Wiehagen, W.J., Lineberry, G.T., Lacefield, W.E., Brnich, M.J., Jr. and L.L. Rethi (1994). The Work Crew Performance Model: A Method for Evaluating Training Performance in the Mining Industry. Bureau of Mines Information Circular 9394.


++